Stepper Motors

Dr. Edward Nava
ejnava@unm.edu

Stepper Motors Description

- Stepper motors are DC motors that move in precise, repeatable, discrete steps.
- They have multiple coils that are grouped in phases.
- By energizing the phases in sequence, the motor will rotate one step at a time.
- With a computer controlled stepping you can achieve very precise positioning and/or speed control. For this reason, stepper motors are the motor of choice for many precision motion control applications.

What are stepper motors good for?

- **Positioning –** Since steppers move in precise repeatable steps, they excel in applications requiring precise positioning such as 3D printers, CNC, Camera platforms and X,Y Plotters. Some disk drives also use stepper motors to position the read/write head.
- **Speed Control –** Precise increments of movement also allow for excellent control of rotational speed for process automation and robotics.
- **Low Speed Torque** - Normal DC motors don't have very much torque at low speeds. A Stepper motor has maximum torque at low speeds, so they are a good choice for applications requiring low speed with high precision.

Stepper Motor Limitations

- **Low Efficiency** – Unlike DC motors, stepper motor current consumption is independent of load. They draw the most current when they are doing no work at all. Because of this, they tend to run hot.
  Limited High Speed Torque - In general, stepper motors have less torque at high speeds than at low speeds. Some steppers are optimized for better high-speed performance, but they need to be paired with an appropriate driver to achieve that performance.
- **No Feedback –** Unlike servo motors, most steppers do not have integral feedback for position. Although great precision can be achieved running 'open loop'. Limit switches or 'home' detectors are typically required for safety and/or to establish a reference position.

Stepper Motor Excitation Modes

- The number of phases in a stepper motor is defined by the number of distinct sets of coils that must be energized in sequence in order to move the rotor.
- A single motor can have a large number of phases; conversely, a single phase can have from two to N windings.
- In general, the greater number of windings energized in a single phase, the greater the power consumption but also the greater the torque.
- The winding design and how you drive those windings play a key role in performance.

Full-Step Single-Coil Mode

- Stepper motors can be excited in any one of several modes, each of which has different characteristics.
- The simplest excitation mode is full-step single-coil mode, or wave drive, in which just one coil of the stator is energized each step.
- It provides minimal torque, and so cannot be used with high loads.
- It does minimize power consumption, however.

Full-Step Dual-Coil Mode

- In this excitation mode, the coils of the stator are energized in pairs.
- If we excite two coils simultaneously, their torque curves superimpose to yield a larger torque.
- The design consumes twice as much voltage or current as single-coil mode, depending on whether it is wired and series or in parallel, but it can produce nearly 100% of rated torque.

Half-Step Single-Coil Mode

- Half-stepping provides a way to double resolution of a stepper motor without modifying the rotor or stator.
- A stepper motor operating in single-coil half-step mode will excite a single pole, then excite two adjacent coils to advance the rotor a half step, then excite another single pole to advance another half step, etc.
- Half-stepping increases resolution with just a change to the drive electronics.

Half-Step Single-Coil Mode

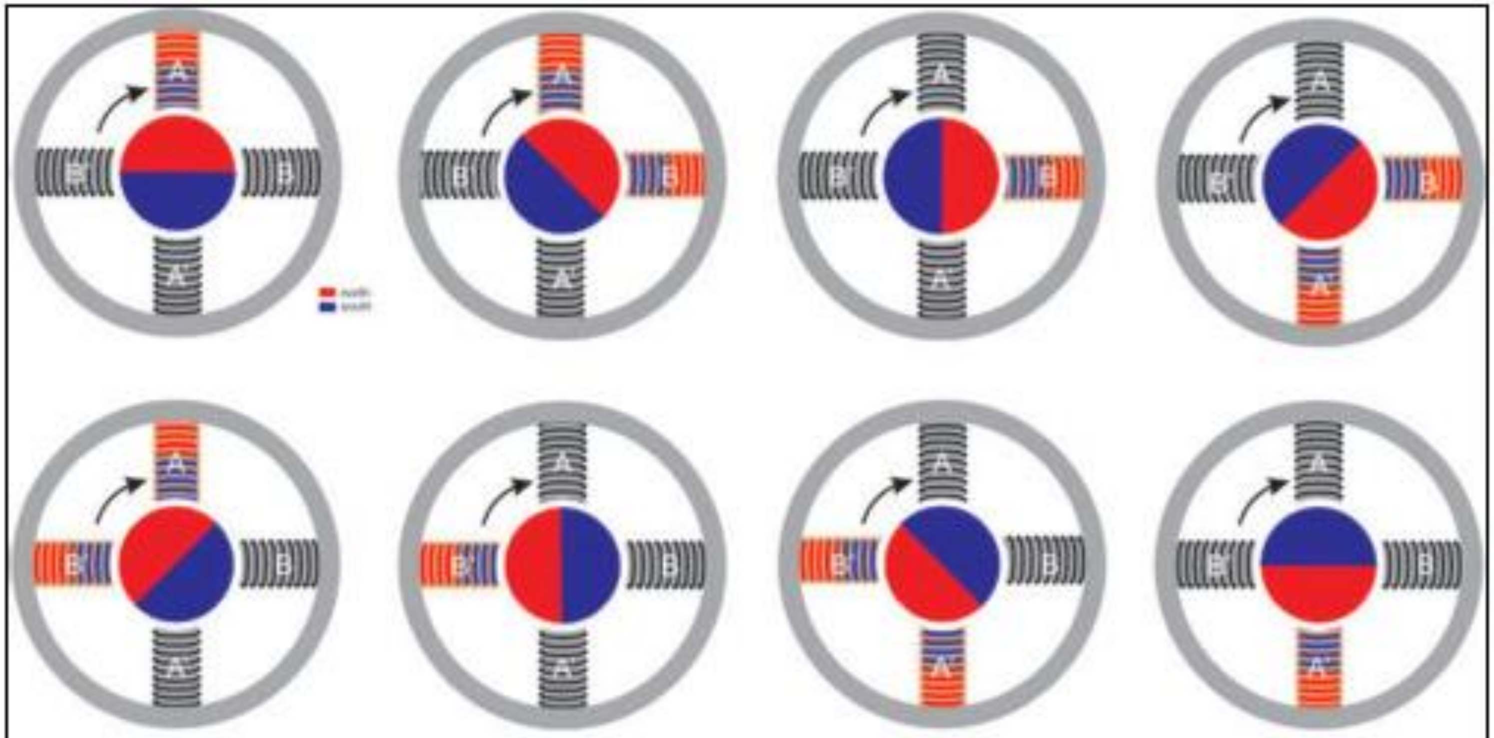


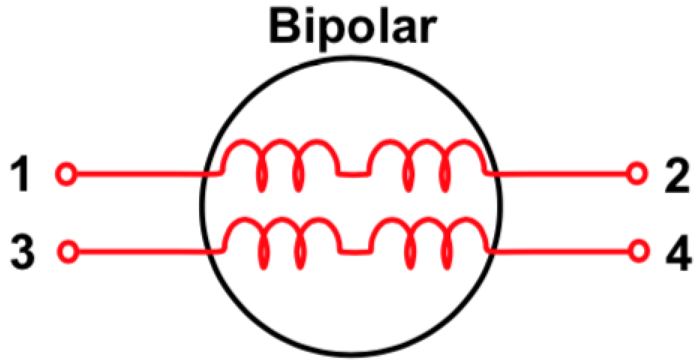
Figure 6: Half-stepping involves energizing a single coil, then two coils, then a single coil, etc., causing the rotor to turn in a series of steps that are one half the step angle. Note that by energizing two coils at once for part of the cycle, the approach can extract more torque from the motor.

Half-step dual-coil mode

- In this mode, two coils are energized the first step, then four, then two, etc.
- Initially, opposing windings with north and south poles are energized to extract more torque out of the first step.
- Next, adjacent coils are energized simultaneously.
- For a two-phase motor, this means all coils are excited simultaneously. In this case, half stepping not only increases resolution, it allows the motor to produce optimum torque.

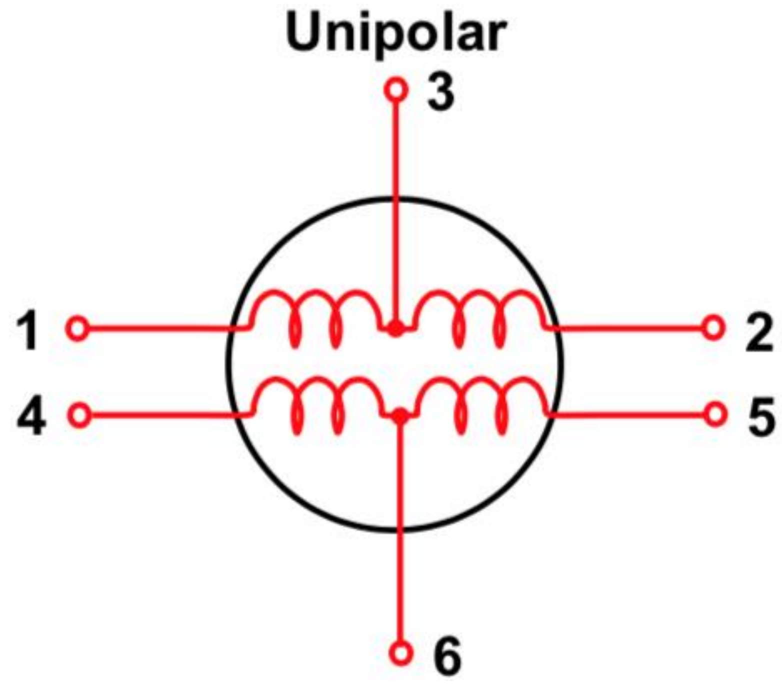
Unipolar and Bipolar Stepper Motors

- These two sub-categories are determined by how the leads from each phase winding is brought out of the motor.
- With a **Bipolar configuration**, each winding lead is brought out separately.
- This type of winding, depending on the voltage applied and to which lead, can produce current flow in two directions. This allows each stator pole to be magnetized to North or South.



Unipolar and Bipolar Stepper Motors

- The **Unipolar configuration** only allows current flow in half of the winding at one time.
- Each winding has a center tap that is brought outside of the motor along with each winding lead.



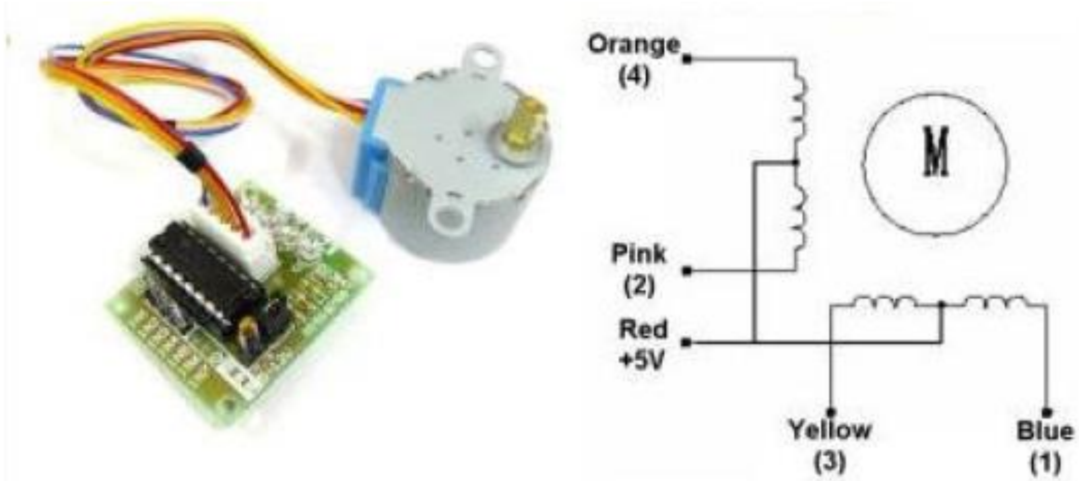
Unipolar vs. Bipolar Stepper Motors

- Comparing both winding configurations, Unipolar motors only allow current flow in half the winding while bipolar offers bidirectional current flow.
- Since torque is related to winding current, Bipolar motors will generate greater torque than unipolar motors.
- Because Unipolar windings are thinner than Bipolar motor windings, more wire is needed thereby increasing the winding’s resistance. This could cause increased power loss via the winding, raising the temperature considerably.
- Using a bipolar motor requires more complex circuitry.
- Since unipolar motors do have both ends of the windings being brought out of the motor, we can connect them in a bipolar configuration and ignore the center tapped lead.

Step Details

- For our experiments, we will use a 28BYJ-48 stepper motor that is configured for unipolar operation.
- The stepper motor has an internal shaft, which is coupled to the external shaft through a gear train.
- Half step mode operation is recommended.
- With a half step mode, the internal shaft moves 5.625 degrees per step. The external shaft then rotates 1/64 of this, or 0.0879 degrees per step.
- In half step mode, the motor output shaft requires approximately 4076 steps to make one revolution.

Half-Step Operation



Half-Step Switching Sequence

Lead Wire Color	---> CW Direction (1-2 Phase)							
	1	2	3	4	5	6	7	8
4 Orange	-	-						-
3 Yellow		-	-	-				
2 Pink				-	-	-		
1 Blue						-	-	-

Using Stepper Motors with the PIC32

- While the signals needed to drive a stepper motor are easily generated by driving digital I/O lines on the PIC32 microcontroller, the I/O lines cannot connect directly to the stepper motor.
- A stepper motor driver with sufficient current drive capability must be used. (ST L293DD)
- We will use the PMOD Stepper Module to drive the motor phases.
- The MX7 Board is not capable of providing sufficient power to drive the stepper motors, so an external power source must be used.